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Dated this 5th day of January, 2004

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(Translation)

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[Document]	Specification	1
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2001-109182

[SPECIFICATION]

[TITLE OF THE INVENTION] Thermal Spray Particles, and Sprayed Components using Thermal Spray Particles

[CLAIMS]

[Claim 1] Thermal spray particles of a rare earth-containing compound characterized by having a bulk density of at least 1.0 g/cm^3, an aspect ratio of up to 2, and a cumulative volume of pores with a pore radius of up to 1 μm which is less than 0.5 cm^3/g.

[Claim 2] The thermal spray particles of a rare earth-containing compound of claim 1 characterized by having a particle size distribution in which a particle diameter D90 corresponds to 90 vol% accumulation is up to 50 μm and having a ratio of a particle diameter D50 corresponds to 50 vol% accumulation in the particle size distribution to a Fisher diameter which is up to 5.

[Claim 3] The thermal spray particles of a rare earth-containing compound of claim 1 or 2 characterized by having a particle size distribution in which a particle diameter D10 corresponds to 10 vol% accumulation is at least 10 μm, and a dispersion index of up to 0.6.

[Claim 4] A thermal sprayed component characterized by having a substrate and a coating of the rare earth-containing compound thermal spray particles of any one of claims 1 to 3 thermally sprayed to the substrate surface.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention]

This invention relates to thermal spray particles of rare earth-containing compound useful for thermal spraying including plasma spraying on the surface of the substrates such as a metal or ceramic to form smooth, dense and highly pure coatings of thermal spray particles of rare earth-

containing compound having no particles stick thereto, and a sprayed component using the spray particles.

[0002]

[Prior Art and Problem to be solved by the Invention]

From the past, it is a common practice in the art to thermally spray metal oxide onto metal or ceramic to form a coating thereon for imparting heat resistance, abrasion resistance and corrosion resistance. The properties of the coating thus formed depend on the spraying conditions as well as the properties of powder particles to be sprayed.

The particle powders suitable for thermal spray coatings typically include (1) a fused and ground powder obtained by melting a starting material in an electric furnace, cooling the melt for solidification, and pulverizing the solid in a grinding machine into particles, followed by classification for particle size adjustment; (2) a sintered and ground powder obtained by firing a raw material, and pulverizing the sintered material in a grinding machine into particles, followed by classification for particle size adjustment; and (3) a granulated powder obtained by adding a raw material powder to an organic binder to form a slurry, atomizing the slurry through a spray drying granulator, and firing the particles, optionally followed by classification for particle size adjustment. The starting material used in the preparation of these powders (1) to (3) is selected as appropriate and has been developed in accordance with the cost and the desired properties of the end spray coating.

[0003]

While plasma processes are involved in the recent semiconductor fabrication art, rare earth-containing compounds have been developed as a wafer processing component in corrosive halide gases because they have high resistance to plasma.

When spray coatings are applied to components in semiconductor manufacturing apparatus, the spray coatings are required ① to contain less impurity elements other than the predominant constituents and ② to have a less irregular,

smooth surface bearing less fines, which means to suppress dusting during wafer processing. To meet these requirements, it becomes crucial how to control the properties of powder particles to be sprayed as well as the spraying conditions.

[0004]

The thermal spray particles have to meet the requirements that ① they can be consistently fed without disintegration at a quantitative rate to the plasma or flame during spraying, ② they are fully melted during spraying (in plasma or flame) and ③ they are highly pure. These requirements are quantitatively expressed by more than ten physical parameters and elemental analysis data of particles.

[0005]

Since the thermal spray particles are fed to the spray gun through a narrow flowpath such as a transportation tube, whether they can be consistently fed at a quantitative rate is largely affected by the flow thereof among other physical parameters.

However, the fused powder or sintered and ground powder resulting from method (1) or (2) has irregular shapes which lead to the drawback that the sprayed coating has large irregularities. Additionally, the fused and ground powder has the other drawback that the content of impurities other than the constituent elements is high, and the sintered and ground powder has the other drawback that impurities are often introduced in the grinding step.

[0006]

Developed as a solution to these problems of the ground powders was the granulated powder obtained by method (3), that is, having the advantage of smooth flow due to the spherical or nearly spherical shape of particles. An additional advantage of the granulated powder is that a relatively pure granulated powder can be readily prepared by reducing impurities in the starting material.

However, a starting powder of a certain type can give rise to the problems that particles of a shape dissimilar to sphere are granulated therefrom and that the starting powder

sticks to granulated particles. An additional problem is that a degradation of flow is incurred particularly when particles have a small diameter.

When a coating is sprayed using the granulated powder, the fines which have not been granulated are incorporated in the coating or stick to the surface of the coating. This causes a substantial amount of dust to generate when the coated component is used in semiconductor equipment or the like. Another problem is wafer processing with a high performance is restricted.

[0007]

In order that particles of metal oxide be thermally sprayed, without dust generation, to form a coating having improved bond strength, the thermal spray particles must be completely melted in the flame or plasma during the spraying step and the supply of the feed particles must be precisely controlled.

Particularly when particles of rare earth-containing compounds are used for thermal spraying, because of their high melting point, they should preferably have a smaller average particle size so that they may be completely melted.

[0008]

In the event where granulated powder is prepared using a spray drying granulator, however, it is difficult to selectively prepare a fraction of particles having a small average particle size. Inevitably, particles having a relatively large average particle size are concomitantly produced. Such particles with a large average particle size have a large weight and are not completely melted when fed into the plasma flame so that they are incorporated in the sprayed coating as unmelted particles, which become one cause of incurring irregularities in the coating. In addition, carbon contained in a binder component is sometimes not fully dried off and remains in the coating as a black spot.

One approach for overcoming the above-mentioned problems is to reduce the particle size of the starting material for eventually holding down coating surface

irregularities. This approach is undesirably accompanied by generation of fines, a degradation of flow and a difficulty of precise metering. As a result, surface irregularities develop and the coating becomes less dense. Furthermore, the fines which stick to particle surfaces without being granulated are not introduced into the plasma flame during the spraying step and are thus kept unmelted so that they are incorporated in or stick to the sprayed coating.

[0009]

The present invention has been accomplished under the above circumstances. An object of the invention is to provide thermal spray, high purity particles of rare earth-containing compound which can be thermally sprayed to form a smooth, dense coating despite the high melting point of the rare earth-containing compound, and without generation of fines. Another object of the invention is to provide a smooth sprayed component having the particles spray coated on a substrate surface without concomitant sticking of fines.

[0010]

[Means for solving the problem and Embodiment of the Invention]

The inventors have earnestly studied to attain the above objects and have found that when the bulk density, cumulative pore volume and aspect ratio of the thermal spray particles of rare earth-containing compound are controlled to the predetermined ranges, their shape is made spherical, and optionally, their particle size distribution is controlled to be sharp. Then the particles generate few or no fines, remain free flowing, have a high density and high strength, and completely melt upon thermal spraying rather than collapsing. A coating obtained by thermally spraying the particles has the advantages of no dust deposition, smoothness, high purity, improved bond, and corrosion resistance, as compared with prior art sprayed coatings.

[0011]

Accordingly, the present invention provides:

1. Thermal spray particles of a rare earth-containing compound characterized by having a bulk density of at least 1.0 g/cm^3, an aspect ratio of up to 2, and a cumulative volume of pores with a pore radius of up to 1 μm which is less than 0.5 cm^3/g,

2. The thermal spray particles of a rare earth-containing compound of 1 characterized by having a particle size distribution in which a particle diameter D90 corresponds to 90 vol% accumulation is up to 50 μm and having a ratio of a particle diameter D50 corresponds to 50 vol% accumulation in the particle size distribution to a Fisher diameter which is up to 5,

3. The thermal spray particles of a rare earth-containing compound of 1 or 2 characterized by having a particle size distribution in which a particle diameter D10 corresponds to 10 vol% accumulation is at least 10 μm, and a dispersion index of up to 0.6,

4. A thermal sprayed component characterized by having a substrate and a coating of the rare earth-containing compound thermal spray particles of any one of 1 to 3 thermally sprayed to the substrate surface.

[0012]

Following is a detailed description of the invention.

Thermal spraying particles are characterized by being formed of a rare earth-containing compound and having a bulk density of at least 1.0 g/cm^3, an aspect ratio of up to 2, a cumulative volume of pores with a radius of up to 1 μm which is less than 0.5 cm^3/g, and being spherical in shape.

As used herein, the "rare earth-containing compound" includes oxides, halides (fluorides, oxyfluorides and chlorides, etc.) and other compounds which contain rare earth elements. Of these, the oxides are preferred because they are vulnerable to sintering. In the following description, reference is made to oxide although the same discussion applies to other rare earth-containing compounds.

The rare earth-containing oxide is selected from the oxides of rare earth elements of Group 3A inclusive of yttrium (Y). Use is preferably made of a heavy rare earth-containing oxide that is an oxide containing at least one rare earth element selected from Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu.

It is understood that compound oxides of the rare earth-containing oxide combined with at least one metal selected from Al, Si, Zr, In, etc. are also useful.

[0013]

If the bulk density is less than 1.0 g/cm^3, particles are less dense and hence, rather weak, with a risk of collapsing upon spraying. The preferred bulk density is 1.2 to 2.5 g/cm^3.

If the cumulative pore volume is 0.5 cm^3/g or more, particles become more irregular on their surface, that is, smooth particles are not obtainable. In order that particles maintain relatively good fluidity even when their particle diameter is reduced, the cumulative volume of pores with a radius of up to 1 μm should be less than 0.5 cm^3/g.

Preferably the cumulative volume of pores with a radius of up to 1 μm is 0.3 cm^3/g or less because the particles are better flowing.

[0014]

The thermal spray particles of rare earth-containing compound according to the invention are spherical in shape. Namely, the particles have an aspect ratio of up to 2. As used herein, the "aspect ratio" is defined as the ratio of major diameter to minor diameter of a particle, which is described as major diameter/minor diameter, that is an index indicating whether the particle shape is approximate to sphere.

An aspect ratio of more than 2 indicates that particles have an irregular, needle, flaky or other shape dissimilar from sphere, leading to disturbed flow. The lower limit of the aspect ratio is, though not critical, preferably close to 1.

The term "spherical" as used herein means the shape of particles having an aspect ratio of up to 2 and thus embraces true spherical to generally spherical shapes.

[0015]

The average particle diameter of the thermal spray particles of a rare earth-containing compound is, though not critical, from 5 to 40 μm, particularly 10 to 35 μm. If the average particle diameter of thermal spray spherical particles is less than 5 μm, some particles may be dispersed in the air without being carried into the plasma flame and gasify and flying in the spraying step, resulting in a reduced yield. If the average particle diameter is more than 40 μm, some particles may remain unmelted during the spraying step and thus form non-fused particles, resulting in less adhesion to the substrate.

As used herein, the "average particle diameter" is a diameter D50 in a particle size distribution as measured by a laser diffraction analyzer

[0016]

In addition to the above described properties, the thermal spray particles of rare earth-containing compound according to the invention have a particle size distribution in which a particle diameter D90 corresponds to 90 vol% accumulation is up to 50 μm and the ratio of D50 which corresponds to 50 vol% accumulation in a particle size distribution to a Fisher diameter is up to 5.

If the particle diameter D90 corresponding to 90 vol% exceeds 50 μm, there is a risk that particles are not completely melted in the plasma flame and thus form non-fused particles, and the coating is contaminated by carbon remained therein and irregularities occur on the coating surface.

[0017]

If the ratio of D50 which corresponds to 50 vol% accumulation in a particle size distribution to a Fisher diameter exceeds 5, there are contained more fractions of coarse particles and fines, which preclude precise feed at a

constant rate. If the above ratio is up to 5, preferably between 1 and 3, the powder is judged to contain less fractions of coarse particles and fines. As pores open at particle surfaces become smaller, the ratio of D50 to Fisher diameter becomes smaller, which enables constant feed. Even when the particle diameter is further reduced, precise feed at a constant rate is possible. As a consequence, using the thermal spray particles in this preferred embodiment, a smooth, dense sprayed coating can be formed.

Fisher diameter is as measured by a Fisher subsieve sizer.

[0018]

The Fisher diameter is calculated from a difference in gas pressure across a powder bed through which gas passes, and thus dependent on the average particle diameter and particle size distribution of the powder and the surface state of particles. Then, in the case of a large average particle diameter, a sharp particle size distribution and/or a smooth particle surface, the Fisher diameter is calculated to be relatively large.

Accordingly, when the ratio of average particle diameter D50 to a Fisher diameter (D50/Fisher diameter) is calculated, a lower ratio suggests a sharper particle size distribution or a smoother particle surface. Particularly, at the same particle size distribution, particles with a lower ratio are judged to have a smoother surface.

[0019]

In a further preferred embodiment, D10 which corresponds to 10 vol% accumulation in a particle size distribution is at least 10 μm, and the particles having a dispersion index of up to 0.6.

This setting of D10 of 10 μm or more and the distribution index of up to 0.6 leads to suppressed generation of fines, a sharp particle size distribution, and improved particle flow, and precludes clogging of a nozzle through which the powder is fed.

It is noted that the dispersion index is defined as:

Dispersion index = (D90-D10)/(D90+D10).

The particles are further improved in flow when they are controlled so as to have a dispersion index of 0.1 to 0.5 and an angle of repose of up to 44°.

[0020]

In a still further preferred embodiment, the thermal spray particles of rare earth-containing compound have a specific surface area of up to 2.0 m^2/g, and more preferably 0.1 to 1.5 m^2/g.

A surface area in excess of 2.0 m^2/g invites a likelihood that particles are not fully fired and become collapsible, causing dust generation.

[0021]

When it is desired that a coating formed on a component by spraying the particles be of high purity and free of colored spots, and impart satisfactory corrosion resistance to the coated component. The thermal spray particles of rare earth-containing compound should preferably have a limited content of each of iron group elements (Fe, Ni, Co, etc.), alkali metal elements (Na, K, etc.) and alkaline earth metal elements (Mg, Ca, etc.) in the particles, that is preferably be up to 5 ppm, calculated as oxide. The lower the content of these metal elements, the better are the results. In most cases, the lower limit is about 0.1 ppm.

It is noted that the content of iron group elements, alkali metal elements or alkaline earth metal elements is measured by ICP (inductively coupled plasma) emission spectrometry after acidolysis of the thermal spray particles of rare earth-containing compound.

[0022]

Secondly, the content of carbon in the thermal spray particles should preferably be up to 100 ppm. A limited carbon content below 100 ppm prevents the bond between particles in the sprayed coating from being weakened by residual carbon, and hence, precludes dust generation. This

indicates that even when granules are formed from a starting powder material using a binder, they are preferably fired so as to minimize the residual carbon, thereby preventing formation of carbide with the starting material.

[0023]

For polycrystalline particles, it is believed that they are more dense as single crystal grains constituting each particle have a larger grain size. The single crystal grains constituting each particle are generally known as crystallites. In the thermal spray particles of rare earth-containing compound according to the invention, the crystallites preferably have a size of at least 25 nm, and more preferably at least 50 nm. When the crystallite size is less than 25 nm, polycrystalline particles with such a small single crystal grain size are not regarded dense in many cases.

Note that the crystallite size is determined by effecting x-ray diffraction analysis and calculating according to Wilson method. According to Wilson method, the crystallite size is normalized to fall in the range of 0 to 100 nm, regardless of the actual size of single crystal grains.

[0024]

The thermal spray particles of rare earth-containing oxide are prepared, for example, by the procedure to be described below.

First, a slurry is prepared by adding rare earth-containing oxide having an average particle diameter of primary particle of 0.01 to 5 μm, preferably 0.01 to 1 μm to a medium such as water or alcohol along with a binder. Granulation from the slurry is then carried out using a granulator such as a tumbling granulator, spray granulator, compression granulator or fluidized bed granulator. The granules are dried and fired in air at 1,200 to 1,800°C, preferably 1,500 to 1,700°C for 1 to 10 hr, yielding free flowing thermal spray particles of rare earth-containing compound having a particle diameter D90 in a particle size

distribution of up to 50 μm, a ratio of D50 to Fisher diameter of up to 5, a bulk density of at least 1.0 g/cm^3, a cumulative pore volume of less than 0.5 cm^3/g, an aspect ratio of up to 2, and a generally spherical shape.

[0025]

Examples of the binder include polyvinyl alcohol (PVA), celluloses such as carboxymethyl cellulose (CMC), hydroxypropyl cellulose (HPC) and methyl cellulose (MC), polyvinyl pyrrolidone (PVP), polyethylene glycol (PEG), polytetrafluoroethylene (PTFE), phenolic resins, and epoxy resins. Usually, the binder is added in an amount of 0.1 to 5% by weight based on the rare earth-containing compound.

[0026]

The thermal spray particles of rare earth-containing compound are generally spherical and relatively small in shape, contain a minimal amount of fines, and have less irregular, smooth surfaces. The particles are thus smoothly flowing and ensure precise metering to a spray nozzle without causing clogging thereof. As a result, a coating obtained by spraying the particles is smooth, dense and substantially free of sticking fines.

[0027]

In a further embodiment, the invention provides a thermally sprayed component which is characterized by comprising a substrate and a coating of the rare earth-containing compound particles thermally sprayed to a surface of the substrate.

The material of the substrate is usually selected from metals, alloys, ceramics and glass, though not limited thereto. Examples include Al, Ni, Cr, Zn, Zr, and alloys thereof, and alumina, aluminum nitride, silicon nitride, silicon carbide, quartz glass, and zirconia.

[0028]

The coating on the substrate surface preferably has a thickness of 50 to 500 μm, more preferably 150 to 300 μm. A coating thickness of less than 50 μm leads to a likelihood

that the sprayed component, on use as a corrosion resistant component, must be replaced by a new one just after faint corrosion. A coating of more than 500 μm thick is too thick and has a risk that delamination occurs within it.

The coating preferably has a surface roughness of up to 60 μm, more preferably up to 40 μm. A surface roughness of more than 60 μm might have a risk of dusting during the service of the sprayed component and presents a larger plasma contact area which may degrade corrosion resistance and allow fines to generate with the progress of corrosion.

Namely, a coating having a surface roughness of up to 60 μm ensures good corrosion resistance and minimizes the sticking of fines to the coating surface. It is then effective for precluding corrosion even in a corrosive gas atmosphere (halide gas plasma). Then the sprayed component is advantageously used as a corrosion resistant component. Since the spray particles of rare earth-containing compound are used, the sprayed component is minimized in dusting as demonstrated by a population of sticking non-fused particles on the coating surface being up to 10 particles/100 μm^2.

[0029]

The spray coated component of the invention is obtainable by plasma spraying or vacuum spraying the rare earth-containing compound particles to the substrate surface to form a coating thereon. The plasma gas used herein is usually selected from nitrogen/hydrogen, argon/hydrogen, argon/helium and argon/nitrogen, though not limited thereto.

The spraying conditions are not critical and may be determined as appropriate in accordance with the type of substrate and rare earth-containing compound particles used and the desired application of the spray coated component.

[0030]

In the spray coated component, the coating should preferably have a limited content of iron group elements, alkali metal elements and alkaline earth metal elements which is each up to 5 ppm, calculated as oxide. This level is

accomplished using spray particles of rare earth-containing compound having a limited metal element content of up to 5 ppm as described above.

Differently stated, when coating is formed using spray particles of rare earth-containing compound having iron group elements, alkali metal elements and alkaline earth metal elements introduced each at a content of more than 5 ppm, the iron group elements, alkali metal elements and alkaline earth metal elements are incorporated in the coating in the same content as in the starting spray particles, which might exert detrimental effects on wafers when the spray coated component is used in semiconductor equipment.

[0031]

As mentioned above, the sprayed component of the invention bears a smooth, dense coating having a surface roughness of up to 60 μm and a high purity as demonstrated by a limited content of iron group elements, alkali metal elements and alkaline earth metal elements which is each 5 ppm or less, calculated as oxide.

Then the sprayed component can be used in equipment where a high purity is crucial, because the sprayed component generates less fines during plasma etching so that the introduction of impurities into wafers being processed is minimized. More specifically, the sprayed component is best suited for use in liquid crystal manufacturing equipment and semiconductor manufacturing equipment, to name a few.

[0032]

[EXAMPLE]

Examples of the invention and Comparative Examples are given below by way of illustration and not by way of limitation.

[0033]

[Example 1]

In 12 liters of deionized water was dissolved 15 g of polyvinyl alcohol (PVA). 8 kg of yttrium oxide having an average particle diameter of 0.5 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry.

Using a spray granulator, the slurry was spray dried to form spherical granules.

The granulated powder was fired in air at 1,600°C for 2 hours, obtaining spherical particles for thermal spraying.

[0034]

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 45 μm. The particles had a bulk density of 1.86 g/cm^3, a specific surface area of 0.6 m^2/g as measured by the BET method, a cumulative volume of pores with a radius of up to 1 μm which was 0.18 cm^3/g, a ratio of an average particle diameter D50 to Fisher diameter of 2.25, and an aspect ratio of 1.01.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 1 ppm of Fe_2O_3 and 2 ppm of CaO. On atomic-absorption spectroscopy analysis, the particles contained 5 ppm of Na_2O and 70 ppm of carbon.

Note that the cumulative pore volume was measured by a mercury penetration auto-scanning porosimeter Model 33 by Yuasa Ionics K.K.

[0035]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 190 μm thick thereon. During the spraying step, the nozzle was not clogged at all. The coating was measured for surface roughness as an indicator of smoothness, finding a Rmax (according to JIS B0601) of 48 μm.

For examining the denseness, the sprayed coating was measured for relative density. After the spray coated substrate was dipped in dilute hydrochloric acid, and the coating was stripped from the substrate, the relative density was measured by Archimedes method. A relative density of 92% was recorded.

[0036]

[Example 2]

In 16 liters of deionized water was dissolved 15 g of CMC (carboxymethyl cellulose). 4 kg of ytterbium oxide having an average particle diameter of 0.4 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry. Using a spray granulator, the slurry was spray dried to form spherical granules. The granulated powder was fired in air at 1,500° C for 2 hours, obtaining spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 36 μm. The particles had a bulk density of 2.2 g/cm^3, a BET specific surface area of 0.5 m^2/g, a cumulative volume of pores with a radius of up to 1 μm which was 0.04 cm^3/g, a ratio of an average particle diameter D50 to Fisher diameter of 2.05, and an aspect ratio of 1.02.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 1 ppm of Fe_2O_3 and 3 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 4 ppm and a carbon concentration of 60 ppm.

[0037]

Using an argon/hydrogen gas plasma with reduced pressure, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 210 μm thick thereon. During the spraying step, the nozzle was not clogged at all. The coating was measured for surface roughness, finding a Rmax of 39 μm.

For examining the denseness, the sprayed coating was measured for relative density as in Example 1. A relative density of 90% was recorded.

[0038]

[Example 3]

In 18 liters of deionized water was dissolved 30 g of PEO (polyethylene oxide). 2 kg of yttrium oxide having an average particle diameter of 0.3 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry.

Using a spray granulator, the slurry was spray dried to form spherical granules. The granulated powder was fired in air at 1,650°C for 2 hours, obtaining spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 28 μm. The particles had a bulk density of 1.6 g/cm^3, a BET specific surface area of 0.7 m^2/g, a cumulative volume of pores with a radius of up to 1 μm which was 0.04 cm^3/g, a ratio of an average particle diameter D50 to Fisher diameter of 2.13, and an aspect ratio of 1.01.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 3 ppm of Fe_2O_3 and 3 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 4 ppm and a carbon concentration of 60 ppm.

[0039]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 200 μm thick thereon. During the spraying step, the nozzle was not clogged at all. The coating was measured for surface roughness, finding a Rmax of 26 μm.

For examining the denseness, the sprayed coating was measured for relative density as in Example 1. A relative density of 91% was recorded.

[0040]

[Example 4]

In 12 liters of deionized water was dissolved 15 g of PVA (polyvinyl alcohol). 8 kg of yttrium oxide having an average particle diameter of 1.1 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry. Using a spray granulator, the slurry was spray dried to form spherical granules. The granulated powder was fired in air at 1,600°C for 2 hours. After fines were removed by a classifier, there were obtained spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 39 μm, a D10 of 23 μm and a dispersion index of 0.25. The particles had an aspect ratio of 1.02, a bulk density of 1.5 g/cm^3, a cumulative volume of pores with a radius of up to 1 μm which was 0.19 cm^3/g, and an angle of repose of 38°.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 1 ppm of Fe_2O_3 and 2 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 5 ppm and a carbon concentration of 70 ppm.

[0041]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 190 μm thick thereon. During the spraying step, the nozzle was not clogged at all.

The surface of the sprayed component was observed under an electron microscope. In the photomicrograph, the number of sticking unmelted particles of a size of less than 5 μm in a 100 μm square area was counted, finding 5 particles.

[0042]

[Example 5]

In 16 liters of deionized water was dissolved 15 g of PEO (polyethylene oxide). 4 kg of ytterbium oxide having an average particle diameter of 0.4 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry. Using a spray granulator, the slurry was spray dried to form spherical granules. The granulated powder was fired in air at 1,500°C for 2 hours. After fines were removed by a classifier, there were obtained spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 37 μm, a D10 of 16 μm and a

dispersion index of 0.40. The particles had an aspect ratio of 1.01, a bulk density of 1.8 g/cm^3, a cumulative volume of pores with a radius of up to 1 μm which was 0.04 cm^3/g, and an angle of repose of 40°.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 1 ppm of Fe_2O_3 and 3 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 4 ppm and a carbon concentration of 70 ppm.

[0043]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 210 μm thick thereon. During the spraying step, the nozzle was not clogged at all.

The surface of the sprayed component was observed under an electron microscope. The number of sticking unmelted particles of a size of less than 5 μm in a 100 μm square area was 3.

[0044]

[Example 6]

In 18 liters of deionized water was dissolved 15 g of MC (methyl cellulose). 2 kg of yttrium oxide having an average particle diameter of 0.3 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry. Using a spray granulator, the slurry was spray dried to form spherical granules. The granulated powder was fired in air at 1,500°C for 2 hours. After fines were removed by a classifier, there were obtained spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 34 μm, a D10 of 16 μm and a dispersion index of 0.36. The particles had an aspect ratio of 1.01, a bulk density of 2.2 g/cm^3, a cumulative volume of pores with a radius of up to 1 μm which was 0.03 cm^3/g, and an angle of repose of 42°.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 3 ppm of Fe_2O_3 and 3 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 4 ppm and a carbon concentration of 50 ppm.

[0045]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 200 μm thick thereon. During the spraying step, the nozzle was not clogged at all.

The surface of the sprayed component was observed under an electron microscope. The number of sticking unmelted particles of a size of less than 5 μm in a 100 μm square area was 2.

[0046]

[Example 7]

In 18 liters of deionized water was dissolved 15 g of PVA (polyvinyl alcohol). 2 kg of yttrium aluminum garnet having an average particle diameter of 4 μm was dispersed therein to form a slurry. Using a granulator, granules were formed from the slurry. They were dried and fired in an electric furnace at 1,500°C for 2 hours. After fines were removed by a classifier, there were obtained spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 36 μm, a D10 of 15 μm and a dispersion index of 0.41. The particles had an aspect ratio of 1.06, a bulk density of 1.1 g/cm^3, and a cumulative volume of pores with a radius of up to 1 μm which was 0.3 cm^3/g.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 4 ppm of Fe_2O_3 and 4 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 5 ppm and a carbon concentration of 65 ppm.

[0047]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 203 μm thick thereon. During the spraying step, the nozzle was not clogged at all.

The surface of the sprayed component was observed under an electron microscope. The number of sticking unmelted particles of a size of less than 5 μm in a 100 μm square area was 2.

[0048]

[Example 8]

In 18 liters of deionized water was dissolved 15 g of PVA (polyvinyl alcohol). 2 kg of ytterbium silicate having an average particle diameter of 3 μm was dispersed therein to form a slurry. Using a granulator, granules were formed from the slurry. They were dried and fired in an electric furnace at 1,500°C for 2 hours. After fines were removed by a classifier, there were obtained spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 33 μm, a D10 of 14 μm and a dispersion index of 0.40. The particles had an aspect ratio of 1.1, a bulk density of 1.9 g/cm^3, and a cumulative volume of pores with a radius of up to 1 μm which was 0.28 cm^3/g.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 3 ppm of Fe_2O_3 and 5 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 4 ppm and a carbon concentration of 72 ppm.

[0049]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 194 μm thick thereon. During the spraying step, the nozzle was not clogged at all.

The surface of the sprayed component was observed under an electron microscope. The number of sticking

unmelted particles of a size of less than 5 μm in a 100 μm square area was 3.

[0050]

[Comparative Example 1]

In 12 liters of deionized water was dissolved 15 g of PVA (polyvinyl alcohol). 8 kg of yttrium oxide having an average particle diameter of 1.1 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry. Using a spray granulator, the slurry was spray dried to form spherical granules. They were fired in air at 1,600° C for 2 hours, obtaining spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle size meter, finding a D90 of 56 μm. The particles had a bulk density of 1.1 g/cm^3, a BET specific surface area of 1.4 m^2/g, a cumulative volume of pores with a radius of up to 1 μm which was 0.55 cm^3/g, a ratio of an average particle diameter D50 to Fisher diameter of 6.93, and an aspect ratio of 1.1.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 3 ppm of Fe_2O_3 and 2 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 5 ppm and a carbon concentration of 80 ppm.

[0051]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 195 μm thick thereon. During the spraying step, the nozzle was not clogged at all. The coating was measured for surface roughness, finding a Rmax of 66 μm.

For examining the denseness, the sprayed coating was measured for relative density as in Example 1. A relative density of 84% was recorded.

[0052]

[Comparative Example 2]

Yttrium oxide having an average diameter of 4 μm, 3 kg, was melted and solidified. This was followed by grinding and classification, obtaining spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured using a laser diffraction particle size meter, finding a D90 of 74 μm. The particles had a bulk density of 2.1 g/cm^3, a BET specific surface area of 0.1 m^2/g, a cumulative volume of pores with a radius of up to 1 μm which was up to 0.01 cm^3/g, a ratio of an average particle diameter D50 to Fisher diameter of 3.05, and an aspect ratio of 2.6.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 55 ppm of Fe_2O_3 and 40 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 10 ppm and a carbon concentration of 92 ppm.

[0053]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating of 190 μm thick thereon. During the spraying step, the nozzle was not clogged at all. The coating was measured for surface roughness, finding a Rmax of 69 μm.

For examining the denseness, the sprayed coating was measured for relative density as in Example 1. A relative density of 91% was recorded.

[0054]

[Comparative Example 3]

In 18 liters of deionized water was dissolved 50 g of PVA (polyvinyl alcohol). 2 kg of ytterbium oxide having an average particle diameter of 1.5 μm and containing less than 0.5 ppm of Fe_2O_3 was dispersed therein to form a slurry. Using a spray granulator, the slurry was spray dried to form spherical granules. They were fired in air at 1,100°C for 2 hours, obtaining spherical particles for thermal spraying.

The spray particles obtained by the above procedure were measured for diameter using a laser diffraction particle

size meter, finding a D90 of 30 μm. The particles had a bulk density of 1.1 g/cm^3, a BET specific surface area of 1.2 m^2/g, a cumulative volume of pores with a radius of up to 1 μm which was 0.58 cm^3/g, a ratio of an average particle diameter D50 to Fisher diameter of 5.14, and an aspect ratio of 1.5.

The particles were measured for impurity concentration by ICP (inductively coupled plasma) emission spectrometry after acidolysis, finding 3 ppm of Fe_2O_3 and 2 ppm of CaO. Atomic-absorption spectroscopy showed a Na_2O content of 5 ppm and a carbon concentration of 130 ppm.

[0055]

Using an argon/hydrogen gas plasma, the particles were vacuum sprayed to an aluminum alloy substrate to form a coating. During the spraying step, the nozzle was clogged and failed to feed the particles.

[0056]

All the spray particles of rare earth-containing oxide obtained in Examples 1-3 have a D90 of up to 50 μm in particle size distribution, a ratio of an average particle diameter D50 to Fisher diameter of up to 5, a bulk density of at least 1.0 g/cm^3, a cumulative volume of pores with a radius of up to 1 μm which was less than 0.5 cm^3/g, and a generally spherical shape with an aspect ratio of up to 2. In addition, the impurity contents are low as demonstrated by a Fe_2O_3, CaO and Na_2O content of each up to 5 ppm.

Using these particles, a sprayed coating of high purity is formed. The coating has a high density and a smooth surface and is strippable with difficulty. When the sprayed component is used in semiconductor manufacturing process, the generation of dust from the sprayed component is minimized. The sprayed component is advantageously used in the application where a high purity is required, for example, liquid crystal manufacturing equipment and semiconductor manufacturing equipment.

The sprayed component has a smooth coating with a surface roughness of up to 60 μm and is useful as a corrosion

resistant component for operation in a corrosive gas atmosphere (such as halide gas plasma).

[0057]

The spray particles of rare earth-containing oxide obtained in Examples 4-8 enable precise metering despite their smaller particle diameter and have a cumulative volume of pores with a radius of up to 1 μm which was less than 0.5 cm^3/g, an aspect ratio of up to 2, a bulk density of at least 1.0 g/cm^3, and a particle size distribution with a D10 of at least 10 μm, a D90 of up to 50 μm, and a dispersion index of up to 0.6. In addition, they are highly pure in that the impurity contents are as low as a Fe_2O_3, CaO and Na_2O content of each up to 5 ppm.

[0058]

Using these particles, a sprayed coating of high purity is formed. Since the number of sticking unmelted particles with a size of less than 5 μm in a 100 μm square area is up to 10, the sprayed component, when used in semiconductor manufacturing process, minimizes the generation of dust therefrom. The sprayed component is advantageously used in the application where a high purity is required, for example, liquid crystal manufacturing equipment and semiconductor manufacturing equipment.

The sprayed component has a smooth coating with a reduced surface roughness and is useful as a corrosion resistant component for operation in a corrosive gas atmosphere (such as halide gas plasma).

[0059]

In contrast, the spray particles of Comparative Example 1 have a D90 as large as 56 μm and a ratio of an average particle diameter D50 to Fisher diameter of 6.93. As a result, a coating obtained by spraying the particles has a large surface roughness and fails to suppress dust generation in the semiconductor manufacturing process.

The spray particles of Comparative Example 2 have a ratio of an average particle diameter D50 to Fisher diameter

as small as 3.05 and provide a coating having a high relative density. However, the iron group element, alkali metal element and alkaline earth metal element are present in the coating in the amounts corresponding to those in the spray particles. When the sprayed component is used in the semiconductor manufacturing process, these impurities can contaminate silicon wafers and become process disturbances. The sprayed component is unsuited in the semiconductor manufacturing equipment and similar application where a high purity is required.

The sprayed component has a rough coating with a surface roughness of 69 μm and allows dust to generate in the semiconductor manufacturing process, which dust undesirably causes to contaminate silicon wafers.

The granulated particles of Comparative Example 3 had a small D 90 of 30 μm and a large ratio of an average particle diameter D50 to Fisher diameter of 5.14 which preclude to feed at a constant rate during spraying step.

[0060]

[Effect of the Invention]

The thermal spray particles of rare earth-containing compound according to the second embodiment of the present invention have a bulk density of at least 1.0 g/cm^3, an aspect ratio of up to 2, a cumulative volume of pores with a radius of up to 1 μm which was less than 0.5 cm^3/g and a generally spherical shape. The particles are thus smoothly flowing and can be precisely fed at a constant rate to a spray nozzle without causing clogging. A coating obtained by spraying the particles is smooth and dense.

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[ABSTRACT]

[Problem]

To provide high purity particles of rare earth-containing compound which can be thermally sprayed to form a smooth, dense coating despite the high melting point of the rare earth-containing compound.

[Means for Solution]

Thermal spray particles of a rare earth-containing compound characterized by having a bulk density of at least 1.0 g/cm^3, an aspect ratio of up to 2, and a cumulative volume of pores with a pore radius of up to 1 μm which is less than 0.5 cm^3/g.

[Selected Drawing] None